History and examination of the thrower’s elbow

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Elbow injuries in the throwing athlete are a result of the high valgus and extension forces acting on the elbow during the throwing motion. These forces result in tensile stress on medial structures, compression stress on lateral structures, and shear stress posteromedially. The correct diagnosis and treatment depends on an accurate history, thorough physical examination, and adequate ancillary testing. Common injuries in the throwing athlete with medial elbow pain include ulnar neuritis, ulnar collateral ligament (UCL) insufficiency or tear (valgus instability), flexor-pronator strain or tendonitis, and medial epicondyle apophysitis or avulsion. Lateral elbow pain may result from osteochondritis dissecans of the capitellum, loose bodies, lateral epicondylitis, radial nerve entrapment, or an olecranon stress fracture. Posterior pain may indicate the presence of valgus extension overload (VEO) syndrome with olecranon osteophyte, trochlear chondromalacia, olecranon stress fracture, or triceps tendinitis.

The physician caring for athletes who participate in overhead sports must have the ability to accurately diagnose and treat all forms of elbow injury and pathology. This requires a thorough understanding of the complex anatomy and function of the elbow joint, along with an understanding of throwing biomechanics.

This article reviews the history and physical examination of the elbow in the overhead athlete. A brief overview of elbow anatomy and throwing biomechanics is included.

Elbow anatomy

The bony anatomy of the elbow results in a modified hinge joint as the distal humerus, radial head, and proximal ulna/olecranon articulate. The elbow may be divided into four anatomic compartments: (1) anterior (humeroulnar and proximal...
radioulnar joints), (2) medial (humeral trochlea with trochlear notch of the ulna), (3) lateral (radiocapitellar), and (4) posterior (ulnar olecranon with humeral olecranon fossa). Elbow stability is provided by both static and dynamic restraints. Static elbow stability results from the congruent bony articulation and ligament attachments, whereas dynamic stability is provided by the various muscle-tendon complexes that attach to or cross the joint.

Cadaveric and biomechanical studies have clarified the relative importance of each of the individual elbow stabilizers [1–6]. These studies have identified several points that are critical in the evaluation of the thrower’s elbow. First, at elbow flexion angles between 20° and 120°, the primary stabilizer to valgus stress is the anterior bundle of the ulnar (medial) collateral ligament, whereas the bony articulation provides the primary restraint to varus stress. The anterior capsule, radiocapitellar joint, and muscle-tendon complexes play a lesser, but still important, role in resistance to valgus stress in the throwing athlete. Second, the congruent articulation of the olecranon with the olecranon fossa is pivotal for elbow stability at less than 20° or more than 120° flexion. Minor shifts in this axis of rotation due to valgus instability may lead to pathologic increase in shear stress at this junction, and the formation of osteophytes and chondral wear. Third, the ulnar nerve lies in a vulnerable position along the posterior aspect of the medial epicondyle in the cubital tunnel, and can be traumatized by relatively small degrees of valgus instability. Finally, the medial flexor-pronator musculature is quite active during the throwing motion and contributes significantly to the dynamic stability of the elbow, especially after injury to the static restraints. Injury may initially present as flexor tendonitis or muscle strain, although the underlying cause is subtle valgus instability. Each of these anatomic relationships is critical in the evaluation of the thrower’s elbow and the understanding of throwing pathoanatomy.

**Biomechanics of throwing**

The etiology of elbow pathology encountered in the throwing athlete can be understood by examining the biomechanics of the elbow joint during the throwing motion. The overhead throwing motion can be broken down into six phases: (1) windup, (2) early cocking, (3) late cocking, (4) acceleration, (5) deceleration, and (6) follow through [7,8]. Large tensile forces medially and compression forces laterally are generated at the elbow during the late cocking and acceleration phases of throwing, whereas deceleration causes high extension and shear stress, especially in the posterior compartment. Biomechanical testing has estimated valgus forces as high as 64 N-m at the elbow during the late cocking and early acceleration phases of throwing, with compressive forces of 500 N at the lateral radiocapitellar articulation as the elbow moves from approximately 110° to 20° of flexion at velocities as high as 3000°/second [7]. This combination of large valgus loads with rapid elbow extension produces tensile stress along the medial compartment restraints (ulnar collateral ligament, flexor-pronator mass, medial
epicondyle apophysis, ulnar nerve), compression stress laterally (radial head, capitellum), and shear stress in the posterior compartment (posteromedial tip of the olecranon, trochlea/olecranon fossa). This phenomenon has been termed VEO and forms the basic pathophysiologic model behind the most common elbow injuries in the throwing athlete [9].

The anterior bundle of the ulnar collateral ligament is the primary restraint to valgus force of the elbow from 20° to 120° of flexion, and is subjected to near-failure tensile stresses during the acceleration phase of the throwing motion. Repetitive near tensile-failure loads applied during throwing result in microtrauma to the anterior band of the UCL and may eventually lead to ligament attenuation or failure. Continued valgus and extension forces combined with subtle laxity may also cause excessive medial soft-tissue stretch, lateral compression, and posterior shear, resulting in the common associated (often secondary) pathologic conditions seen in the thrower’s elbow.

History

Evaluation of elbow pain in the throwing athlete must begin with a thorough and detailed throwing history, including duration of symptoms, location, and timing during the throwing motion, and associated symptoms [10].

Duration

Elbow pain in the thrower often presents as an acute event superimposed on a chronic overuse injury. Acute trauma to a normal ligament, such as with an elbow dislocation, results in UCL disruption and injury that may heal well with conservative treatment; however, in the thrower, acute medial ligament pain may actually represent an acute-on-chronic injury to a chronically attenuated ligament. Valgus instability due to UCL injury or attenuation must always be ruled out as the primary underlying cause of any associated pathologic condition in the thrower’s elbow.

Approximately 60% of patients with ulnar collateral ligament injury present after an acute episode, although many report prior medial elbow pain or treatment for flexor-pronator tendonitis or ulnar neuritis [11,12]. Valgus extension overload with posteromedial olecranon osteophytes, olecranon stress fractures, ulnar neuritis, flexor-pronator tendonitis, and radiocapitellar compression often presents with a slow, insidious onset of pain. Loose bodies may present acutely with mechanical symptoms of locking or catching, and the immature athlete may develop acute medial elbow pain with avulsion of the medial epicondyle apophysis.

A prior history of shoulder injury or pain may alert the clinician to a variation in throwing mechanics or muscular strength as the etiology for the onset of elbow pain. Complaints related to the cervical spine and nerve-root compression or radiculopathy must be investigated. Anatomic abnormalities caused by prior
trauma, such as fracture deformity, or previous surgery, especially ulnar nerve transposition, should be noted.

**Timing (throwing phase)**

The time of onset of symptoms and the phase of throwing during which pain is experienced are important [7]. In athletes with medial elbow instability (UCL insufficiency), nearly 85% will experience pain during the acceleration phase of throwing, whereas fewer than 25% will experience pain during the deceleration phase [13].

Pain during late acceleration and cocking is often due to medial tensile stress (UCL, medial epicondylitis, flexor-pronator strain, ulnar neuritis), whereas pain with deceleration and follow through often signifies posterior pathology (VEO, olecranon osteophyte formation, loose bodies, triceps tendonitis) [9,14].

**Location**

The anatomic location of elbow pain allows the clinician to formulate an early differential diagnosis [15]. Medial pain may represent UCL insufficiency or tear, medial epicondylitis, ulnar neuritis or ulnar nerve subluxation, flexor-pronator strain or tear, or medial epicondylitis or avulsion (in the skeletally immature athlete). Lateral pain is often caused by radiocapitellar compression with chondral wear, olecranon stress fracture, lateral epicondylitis, radial nerve entrapment syndrome, loose bodies, or osteochondritis dissecans of the capitellum (in the immature athlete). Posterior pain may signify VEO with olecranon osteophyte formation, loose bodies, olecranon stress fracture, triceps tendonitis, or olecranon traction apophysitis (in the immature athlete).

The specific location of tenderness should be elicited and is discussed in the physical examination section below. Pain associated with medial epicondylitis may radiate from the flexor origin down the forearm, and ulnar neuritis may present with either localized pain or paresthesias in the ring and small fingers. Patients with ulnar nerve subluxation may report a recurrent snapping sensation just proximal to the medial epicondyle as the elbow progresses from extension to flexion [16–18].

**Associated symptoms**

Any neurologic or vascular complaints should be accurately documented. Symptoms such as cold intolerance, numbness or tingling in the hand or fingertips, shooting sensations, and tendency to drop objects may be the earliest signs of significant neurovascular pathology [19]. Dull aching pain and a tendency to early fatigue may represent early nerve compression from median nerve compression (pronator syndrome) or radial nerve entrapment (supinator syndrome). Complete motor loss or clumsiness with fine muscle movements of the hand often indicates more severe nerve injury.
Aggravating or alleviating factors

Many athletes have learned to reproduce or alleviate their symptoms by forearm or elbow position. Resisted pronation or flexion often aggravates the pain of medial epicondylitis or flexor-pronator muscle injury, whereas active supination may increase radial nerve entrapment symptoms. Terminal extension causes posterior pain with valgus extension overload, whereas maximal flexion may produce pain or paresthesias related to ulnar neuritis.

Pitch type and intensity may also cause symptom onset. Patients with UCL insufficiency often remain asymptomatic at low levels of throwing intensity, but have pain with attempts to “cut it loose” at greater than 75% effort. Others can long toss at 120 feet with high velocity, but are unable to throw from a mound without significant pain. Studies have noted a trend in players with UCL insufficiency toward more pain with breaking pitches and less pain throwing fastballs or change-ups [7,12].

Previous treatment

The clinician should investigate details of any previous treatment on the throwing arm. Prior shoulder or elbow injuries or surgery may be important in determining the etiology of the current symptoms. It is common for throwers to complain of elbow symptoms when returning from treatment for shoulder pathology, and vice versa.

Prior medial elbow pain treated as flexor tendonitis or ulnar neuritis that fails to resolve must lead the examiner to closely evaluate the competence of the UCL and the possibility of valgus instability as the primary pathology. Prior lateral pain treated as lateral epicondylitis without resolution may represent radial nerve entrapment or radiocapitellar compression syndrome.

Persistent posterior pain not alleviated by arthroscopic olecranon osteophyte excision for VEO may actually represent underlying valgus instability. Azar and colleagues have reported a high association of UCL insufficiency requiring ligament reconstruction and prior olecranon osteophyte excision [12]. It is not clear whether the osteophyte excision led to the eventual failure of the UCL, or the symptoms were initially mistaken for VEO when the primary pathology was valgus instability.

Team/season concerns

Level of play and time of season also must be considered in the spectrum of injury and treatment options in throwing athlete. Most UCL injuries occur during regular season competition, whereas injuries due to improper mechanics or training (flexor tendonitis) often present during early preparation or spring training [12]. The clinician should specifically ask about warm-up, preseason preparation (“getting the arm in throwing shape”), and excessive pitch counts, because all have been implicated as important factors in elbow injury [7,20].
Acute injuries are often seen when a position player attempts to begin pitching during a contest without adequate warm-up or pre-event preparation. Overthrowing, or trying to exceed maximal velocity, is seen during tryouts or “shows” and may lead to injury. Year-round throwing without adequate rest and recovery has been debated as a possible cause of the apparent increased incidence of elbow injuries (especially UCL) in the young thrower.

Time of season and level of play may be important factors in determining potential treatment options. Professional pitchers must consider contractual issues, and the clinician may be wise to include input from family members, coaches, trainers, agents, and other support staff during the evaluation and treatment process.

**Physical examination**

A thorough physical examination will often result in proper diagnosis without the necessity of additional ancillary tests. The clinician should perform a reproducible complete examination with inspection, range of motion, and palpation, which commonly leads to a focused set of specific tests to better define the pathology.

**Inspection**

The physical examination of the elbow begins with inspection to assess the resting position of the elbow. The carrying angle is the angle between a line drawn along the axis of the humerus and a line drawn along the axis of the forearm. The normal carrying angle is 11° of valgus in adult males and 13° of valgus in adult females [21]. An increase in the carrying angle when compared with the opposite side may be due to previous trauma or developmental abnormality; however, in throwing athletes it is not uncommon to find increased valgus in the throwing elbow due to adaptive changes to repetitive stress. In professional throwers it is not uncommon to find valgus angles greater than 15° [22]. Increased valgus deformity may result in a lengthened ulnar nerve course and increased susceptibility to traction injury and ulnar neuritis.

Swelling or ecchymosis may indicate acute injury to ligament, bone, or muscle-tendon complex; however, some degree of muscular hypertrophy is common in the throwing arm and may represent adaptive changes.

**Range of motion**

Normal range of motion (ROM) at the elbow joint is from full extension (0°) to 140° flexion, and from 75° pronation to 85° supination [23]; however functional ROM has been shown to be approximately 30° flexion to 130° degrees flexion and 50° pronation/supination [24]. Throwing athletes often present with loss of elbow extension, which may be developmental or pathologic. Flexion
contracture of up to 20° is not uncommon in the overhead athlete, and if asymptomatic is not considered pathologic.

Both active and passive ROM should be determined. Painful loss of motion may be due to effusion, soft-tissue swelling, bony hypertrophy, or osteophyte formation. The “end feel” of the extremes of motion is important. A solid end point in flexion may indicate osteophyte formation in the coronoid fossa of the anterior humerus, whereas a firm end point with terminal extension may be due to a posterior osteophyte on the olecranon tip or in the olecranon fossa. A soft end point may be due to an effusion, soft tissue swelling, or capsular contracture. Crepitance during ROM often indicates chondral injury or loose bodies.

**Palpation**

Palpation of individual structures is performed to determine the site of pain, and should be performed in a sequential manner to rule out associated pathologic conditions. The lateral soft spot at the junction between the radial head, capitellum, and olecranon is palpated to assess the presence of a joint effusion. The presence of any soft-tissue masses should be noted.

Palpation of the UCL is performed with the elbow in approximately 50° to 70° flexion, because this will move the overlying medial muscle mass anterior to the fibers of the UCL (Fig. 1). The ligament should be palpated along its entire course, beginning at its origin from the inferior aspect of the medial epicondyle and progressing distally to its insertion onto the sublime tubercle of the proximal medial ulna. Pain to palpation along the ligament may indicate pathology ranging from partial intrasubstance injury and attenuation to complete rupture.

Palpation of the medial epicondyle and flexor muscle mass is accomplished by moving distal and slightly anterior to the medial epicondyle. Injury most often

Fig. 1. Palpation of the anterior band of the ulnar collateral ligament is performed with the elbow in 70° to 90° flexion. The UCL is palpated from the medial epicondyle of the humerus to the sublime tubercle of the medial ulna.
occurs at the pronator teres (PT) and flexor carpi radialis (FCR) tendons and is felt anterior to the course of the UCL. Pain may be aggravated by resisted wrist flexion and forearm pronation. Ligament (UCL) injury may be differentiated from epicondylitis by performing the valgus stress test, with the wrist in passive flexion and pronation to eliminate tension on the flexor-pronator mass [25]. Medial pain with this modification likely indicates UCL injury rather than medial epicondylitis or muscle injury.

Palpation of the lateral structures includes the radial head, capitellum, lateral epicondyle, and extensor muscle mass. Crepitance may indicate radiocapitellar chondral injury or the presence of loose bodies. Lateral epicondylitis generally evokes pain with resisted wrist extension, whereas application of an axial load to the lateral elbow with neutral wrist position and repeated pronation and supination may exacerbate symptoms of radiocapitellar chondral degeneration, known as the radiocapitellar compression test [26]. Radial nerve compression syndrome often causes aching and deep pain to palpation in the middle and distal forearm. Maximal tenderness with lateral epicondylitis is usually anterior and slightly distal to the lateral epicondyle. Loss of motion associated with lateral pain to palpation may indicate osteochondritis dissecans (OCD) of the capitellum. Rarely, symptomatic thickening of a posterolateral synovial plica may cause reproducible pain and mechanical popping along the posterolateral aspect of the radiocapitellar articulation.

Anterior soft tissues palpated include the biceps tendon, brachialis tendon, and anterior capsule. Posterior palpation is focused on the olecranon tip and triceps tendon. Posteromedial olecranon tenderness usually indicates VEO with osteophyte formation, whereas posterolateral pain may be associated with an olecranon stress fracture.

The neurovascular structures about the elbow should be palpated, with specific attention to palpation of the ulnar nerve. Gentle palpation or percussion of the ulnar nerve should not cause any pain or discomfort in the healthy elbow. Palpation should begin above the medial epicondyle, through the cubital tunnel, and distally as far as possible into the flexor carpi ulnaris muscle mass. Gentle pressure on the nerve should be exerted above the medial epicondyle to ensure that the nerve will not subluxate out of the cubital tunnel. Tinel’s sign is elicited by direct percussion along the entire course of the nerve causing paresthesias in the ring and small fingers. Subluxation of the ulnar nerve may cause significant discomfort or paresthesias. Typically, the unstable ulnar nerve will dislocate anterior to the medial epicondyle while the elbow is moved from extension to flexion [17,27]. While palpating the ulnar nerve above the cubital tunnel, the distal medial aspect of the triceps tendon should be palpated. Anomalous bands of the distal triceps insertion have been described as a cause of ulnar nerve impingement and may cause a snapping sensation as they move across the medial epicondyle [18].

Distal pulses and sensation in all nerve distributions of the upper extremity should be assessed. Strength testing of the biceps, triceps, pronation, supination, and wrist flexion and extension should be performed. Strength should be compared with the opposite nonaffected extremity.
Specific tests

Valgus stress testing is performed to evaluate injury to the anterior bundle of the UCL. Although cadaveric cutting studies have suggested 70° to 90° elbow flexion as the optimal position to isolate the contribution of the UCL to valgus stability, it is difficult to control humeral rotation and apply valgus stress at that angle. Therefore, testing is best performed at 20° to 30° elbow flexion with the forearm pronated. Valgus stress testing may be performed with the patient seated upright, supine, or prone. Norwood and colleagues described valgus stress testing of the elbow with the forearm supinated at 15° to 20° elbow flexion to unlock the olecranon from the olecranon fossa [28]. It is now recognized that forearm pronation prevents subtle posterolateral instability from mimicking medial laxity [29].

To perform the valgus instability test on the right elbow in the seated or supine position, the examiner stabilizes the humerus with the left hand just above the humeral condyles, and applies a valgus moment with the right hand while grasping the patient’s pronated forearm (Fig. 2). In the prone position, the examiner stabilizes the humerus in 90° shoulder abduction with the right hand above the humeral condyles, flexes the elbow 20° to 30°, and applies valgus stress with the left hand on the patient’s pronated forearm (Fig. 3). Comparison is made with the opposite elbow for both increased medial opening and reproduction of pain. Detecting significant instability is often very subtle in the throwing athlete because of the relatively small degree of medial opening on examination, even in the face of significant ligament injury. Field and colleagues have demonstrated that complete sectioning of the anterior bundle of the UCL only increases medial opening by 1 mm to 2 mm [30,31].

Fig. 2. The valgus instability test on the right elbow in the supine position. The examiner stabilizes the humerus with the left hand just above the humeral condyles and applies a valgus moment with the right hand while grasping the patient’s pronated forearm.
Veltri and colleagues described the “milking maneuver” to evaluate valgus stability [32]. With the patient seated, the examiner grasps the thrower’s thumb with the arm in the cocked position (90° shoulder abduction and 90° elbow flexion) and applies valgus stress by pulling down on the thumb (Fig. 4). This position is felt to be similar to pulling down on the teats when milking a cow,
hence the name. A variation of this test is performed with the examiner beginning in the position of the milking maneuver and slowly extending the elbow from 90° flexion to 20° flexion while applying valgus stress (pulling the thumb toward the floor).

Although posterolateral instability is uncommon in the throwing athlete, overhead athletes may present with chronic elbow instability after a traumatic elbow dislocation. Several tests have been described to evaluate the lateral ligament complex [29,33]. Pseudovalgus instability may be present with apparent valgus laxity in supination but not in pronation. Although the lateral pivot shift test and posterolateral rotatory drawer test are sensitive for detecting lateral instability, they often require general anesthesia to reproduce the radial head subluxation and subsequent reduction.

The valgus extension overload test is performed to detect the presence of a posteromedial olecranon osteophyte or olecranon fossa overgrowth. The examiner stabilizes the humerus with one hand, and with the opposite hand, pronates the forearm and applies a valgus force while quickly maximally extending the elbow (Fig. 5). A positive valgus extension overload test causes pain posteromedially as the olecranon tip osteophyte engages into the olecranon fossa.

If surgical reconstruction of the UCL is considered, the examiner should determine whether the patient has a palmaris longus tendon in the ipsilateral or contralateral forearm (Fig. 6). The palmaris longus is the most common tendon graft used for UCL reconstruction, and is present in approximately 80% of throwing athletes [12]. If the palmaris longus is absent, other graft choices such as gracilis or plantaris tendon must be evaluated.

Fig. 5. The valgus extension overload test. The examiner stabilizes the humerus with one hand and with the opposite hand, pronates the forearm and applies a valgus force while quickly maximally extending the elbow.
Adolescent thrower

The presence of open physes in the skeletally immature athlete provides the clinician with a unique set of diagnostic challenges. The term “little leaguer’s elbow” has been used to describe various pathologic conditions in the immature athlete, including medial epicondyle apophysitis or avulsion, OCD of the humeral capitellum, olecranon apophysitis, or delayed closure of the medial epicondyle or olecranon apophysis.

Lyman and coworkers evaluated the frequency of elbow pain in a prospective study of 298 youth pitchers [34]. Twenty-six percent of pitchers reported elbow pain during a study period of two consecutive seasons. Risk factors for elbow pain included larger body size (increased weight, decreased height), older age, and overuse (playing baseball outside the league, arm fatigue, throwing more than 600 pitches during the season).

Although acute injury may occur in the adolescent thrower, most injuries are caused by chronic overuse as the stress of the throwing motion is applied to the growing skeleton. Whereas the adult elbow often fails at the ligament-bone junction, adolescent injuries generally occur at the relatively weak apophysis.

Ecchymosis and acute swelling along the medial elbow most often represents avulsion of the medial epicondyle apophysitis, whereas lateral swelling may indicate OCD of the capitellum with fragmentation and loose body formation. Insidious onset of medial pain and tenderness along the medial epicondyle usually represents overuse apophysitis rather than ligament injury or flexor muscle tendinitis. Lateral pain in the adolescent should raise the suspicion for OCD of the capitellum, whereas posterior pain often represents olecranon apophysitis. The examiner must be wary, however, because UCL injury can occur in the skeletally immature athlete similarly to the adult and may not resolve with simple rest, as would be expected with apophysitis.
Summary

The elbow of the overhead throwing athlete is subjected to repetitive near-failure loads as energy is transferred from the trunk to the hand during the throwing motion. The physician caring for the thrower must have a thorough understanding of the complex anatomy and function of the elbow joint, along with an understanding of throwing biomechanics, to accurately diagnose and treat elbow pathology. A thorough and detailed throwing history and physical examination will often lead the examiner to the proper diagnosis without reliance on ancillary testing. Specific tests have been described that may aid in differentiating similar pain patterns and pathologic processes. Elbow pain in the adolescent athlete is common and often represents a growth-plate injury. In the adult overhead athlete, a high index of suspicion for injury or insufficiency of the ulnar collateral ligament should underlie any evaluation of elbow pain.

References